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## DECLARATION

I, Kazuo O'OKA c/o SHIGA INTERNATIONAL PATENT  
OFFICE, 2-3-1 Yaesu, Chuo-ku, Tokyo, Japan, understand both English  
and Japanese, am the translator of the English document attached, and do  
hereby declare and state that the attached English document contains an  
accurate translation of Japanese Unexamined Patent Application, First  
Publication No. 2000-176030, filed on June 4, 2001 in Japan and that all  
statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

This 15th day of December, 2003

Kazuo Ooka  
Kazuo O'OKA

[Document Type] Specification

[Title of the Invention] CONTROL APPARATUS FOR STARTING FUEL CELL VEHICLE

[Claims]

[Claim 1]

1. A control apparatus for starting a fuel cell vehicle comprising:  
a fuel cell for supplying electric power to a load;  
a power storage unit for assisting a supply of electric power to the load and for storing energy generated by the fuel cell;  
fuel cell driving means for driving the fuel cell while supplying reaction gases to the fuel cell; and  
current limiting means for limiting an output current from the fuel cell;  
wherein, at the time of starting the fuel cell, the power storage unit supplies electric energy to the fuel cell driving means and the current limiting means prohibits the fuel cell from outputting an output current until an output voltage of the fuel cell reaches a predetermined voltage, and  
wherein, after the output voltage rises to more than the predetermined voltage, the current limiting means limits the output current of the fuel cell to below a predetermined current value until a difference between the output voltage of the fuel cell and a terminal voltage of the power storage unit reaches a predetermined voltage difference.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a control apparatus for starting a fuel cell vehicle, and in particular, relates to a technique for starting a fuel cell in a hybrid-type power source device provided with a power storage unit, which assists a supply of electric power from the fuel cell.

[0002]

[Prior Art]

Conventionally, as a vehicle having a solid polymer membrane type fuel cell, a hybrid-type fuel cell power generation system is known, which comprises a fuel cell

and a power storage unit in order to improve the output responsiveness of the fuel cell that is driven by fuel gas supplied. The solid polymer membrane type fuel cell is typically made of a plurality of cells, each of which is formed by sandwiching a solid polymer electrolyte membrane comprising a solid polymer ion exchange membrane and the like between an anode and a cathode. And, the power storage unit is typically a battery or a capacitor (electric double layer capacitor or another type capacitor).

[0003]

[Problems to be Solved by the Invention]

Incidentally, in the above conventional hybrid-type fuel cell power generation system, at the time of starting the fuel cell, first, air is supplied to the pressure control valve at the fuel side. And, fuel gas is supplied to the fuel electrode of the fuel cell with a pressure depending on the pressure of the air supplied. Then, power generation is started.

Thus, before starting the fuel cell, the power storage unit supplies electric driving power to devices such as a compressor, which supplies air, and others. In addition to auxiliary devices for driving the fuel cell and various control devices, the power storage unit also supplies electric power to, for example, the motor for driving the vehicle when the vehicle is started immediately after the fuel cell is started. As a result, the energy stored in the power storage unit is reduced, and, at the same time, the terminal voltage of the power storage unit is also reduced.

In this case, if the power storage unit, in which the terminal voltage has been reduced, is connected directly to the fuel cell immediately after the fuel cell is started, a large electric current rapidly flows from the fuel cell into the power storage unit. Thus, in the process of the terminal voltages for both units being changed toward an equilibrium voltage, the terminal voltage for the fuel cell is reduced rapidly. As a result, there is a danger of losing hydrogen gas and water content in the solid polymer electrolyte membrane of the fuel cell through evaporation, or degrading the durability of the fuel cell.

[0004]

The present invention is provided in view of the background situation described above, and it is an object of the present invention to provide a control apparatus for starting a fuel cell vehicle, which is capable of preventing an excessive reduction of the terminal voltage of a fuel cell, at the time of starting the fuel cell, for example, when the vehicle is started or other times.

[0005]

[Means for Solving the Problem]

In order to accomplish the objective of solving the problem described above, a control apparatus for starting a fuel cell vehicle according to claim 1 of the present invention comprises a fuel cell (for example, a fuel cell 11 in the embodiment described later) for supplying electric power to a load (for example, a driving motor 13, a PDU 14, an air compressor 15 and the like, in the embodiment described later); a power storage unit (for example, a power storage unit 12 in the embodiment described later) for assisting the supply of electric power to the load and for storing energy generated by the fuel cell; a fuel cell driving means (for example, an air compressor 15 in the embodiment described later) for driving the fuel cell while supplying reaction gases (for example, hydrogen gas and air in the embodiment described later) to the fuel cell; and a current limiting means (for example, a secondary pre-charge portion 17 in the embodiment described later) for limiting an output current from the fuel cell; wherein, at the time of starting the fuel cell, the power storage unit supplies electric energy to the fuel cell driving means and the current limiting means prohibits the fuel cell from outputting an output current until an output voltage (for example,  $V_{fc}$  in the embodiment described later) of the fuel cell reaches a predetermined voltage (for example,  $V_{MOT} \rightleftharpoons V_{st} \rightleftharpoons V_{fc}$  in the embodiment described later), and, after the output voltage rises to more than the predetermined voltage, the current limiting means limits the output current of the fuel cell to below a predetermined current value until the difference between the output voltage of the fuel cell and a terminal voltage (for example, a terminal voltage  $V_{st}$  in the embodiment described later) of the power storage unit reaches a predetermined voltage difference (for example, a predetermined voltage difference  $\Delta V$  in the embodiment described later).

[0006]

According to the control apparatus for starting the fuel cell vehicle with the structure described above, since current limiting means, which limits the output current at the time of starting the fuel cell, is provided, it is possible to prevent the terminal voltage of the fuel cell from being reduced rapidly.

That is, at the time of starting the fuel cell, first, fuel cell driving means (such as an air compressor and the like), in addition to supplying air to the air electrode, supplies air, as a signaling pressure, to the pressure flow control valve used for supplying hydrogen gas to the fuel electrode as fuel. In this case, the power storage unit supplies electric power to the fuel cell driving means and, as a result, the remaining charge of the power storage unit goes down and, at the same time, the terminal voltage of the power storage unit also goes down. Here, by providing a pre-charge circuit, which has a resistor having a relatively large resistance value, to the power storage unit,

the output current from the power storage unit can be directed through the resistor to the fuel cell driving means, the PDU of the driving motor, and the like. Thus, it is possible to prevent a large electric current from flowing rapidly and, thus, development of a so-called inrush current can be prevented.

[0007]

In this case, by using current limiting means such as a DC-DC chopper, the output current from the fuel cell can be inhibited until the output voltage of the fuel cell reaches a predetermined voltage, and after the output voltage of the fuel cell becomes equal to or above the predetermined voltage, the output current from the fuel cell can be limited. Thus, it is possible to prevent a large current from flowing rapidly from the fuel cell into the power storage unit whose terminal voltage is low.

And, until the difference between the terminal voltage of the fuel cell and the terminal voltage of the power storage unit becomes equal to or below a predetermined value (including 0), a large current is prevented from flowing rapidly from the fuel cell into the power storage unit. Thus, as the power storage unit is charged gradually by the limited output current, the terminal voltage of the power storage unit and the terminal voltage of the fuel cell are changed gradually to an equilibrium voltage with respect to each other. Typically, when the terminal voltage of the fuel cell becomes much lower than a predetermined voltage during the transitional stage toward the equilibrium voltage, the following problems may be developed. That is, hydrogen gas or the water content in the solid polymer electrolyte membrane of the fuel cell is evaporated or the durability of the fuel cell is decreased. However, since the terminal voltage of the fuel cell does not become lower than a predetermined voltage, the above described problems are avoided and, thus, it is possible to lengthen the service life of the fuel cell.

[0008]

Furthermore, by using a DC-DC chopper as current limiting means and by changing the duty ratio of the input pulse current for controlling the chopping operation, the output current can be easily controlled. Thus, it is possible to reduce the time to reach an equilibrium voltage for each terminal voltage of the fuel cell and the power storage unit, while preventing the terminal voltage of the fuel cell from becoming too low.

And, even when the voltage difference between the terminal voltages of the fuel cell and the power storage unit is large, by using a DC-DC chopper as current limiting means, a problem such as arc welding of a contact point at the time of opening the contact point can be prevented. The arc welding problem tends to be generated in

a contact type switching system where an electric current is switched to an output path through a resistor.

[0009]

[Embodiments of the Invention]

Hereinafter, an embodiment of a control apparatus for starting the fuel cell vehicle according to the present invention is described with reference to the attached drawings. Fig. 1 is a diagram showing the structure of a fuel cell vehicle 1 that is provided with a control apparatus 10 for starting the fuel cell vehicle. Fig. 2 is a diagram showing the main structure of the control apparatus 10 for starting the fuel cell vehicle shown in Fig. 1. Fig. 3 is a diagram showing a configuration of a DC-DC chopper 17a shown in Fig. 1.

A fuel cell vehicle 1 of this embodiment is provided with a hybrid-type power source system including a fuel cell 11 and a power storage unit 12, and these power sources supply electric power to a driving motor 13 which generates driving power; the driving power generated by the motor is transmitted to the driving wheels through a transmission T/M, which consists of either an automatic transmission or a manual transmission. When the driving power is transmitted from the driving wheels to the driving motor 13 during deceleration of the fuel cell vehicle, the driving motor 13 acts as a generator and generates what is called regenerative braking power, and the kinetic energy of the vehicle body is recovered as electric energy.

[0010]

A control apparatus 10 for starting the fuel cell vehicle according to the present embodiment comprises, for example, a fuel cell 11, a power storage unit 12, a driving motor 13, a PDU (Power Drive Unit) 14, an air compressor 15 as one of the auxiliary devices for driving the fuel cell, a primary pre-charge portion 16, a secondary pre-charge portion 17, and an ECU 18.

[0011]

The driving motor 13 is formed of a permanent magnet type three-phase AC (alternating current) synchronous motor utilizing, for example, a permanent magnet as a magnetic field system, and the driving motor 13 is driven and controlled by the three-phase AC power supplied by the PDU 14.

The PDU 14 is provided with a PWM inverter comprising switching elements such as an IGBT and the like. And based on a torque command provided by the ECU command, the PDU 14 converts a DC power output from the fuel cell 11 and the power storage unit 12 into three-phase AC power to be supplied to the driving motor 13.

[0012]

The fuel cell 11 comprises a stack of multilayer cells, each of which is formed by sandwiching both side surfaces of a solid polymer electrolyte membrane (for example, a solid polymer ion exchange membrane and the like) between an anode and a cathode. And, the fuel cell is provided with a hydrogen electrode, to which hydrogen gas is supplied as a fuel, and an air electrode, to which air containing oxygen as an oxidizing agent is supplied. And in the fuel cell 11, electric generation is performed at the cathode by electrochemical reactions between oxygen and hydrogen ions after the hydrogen ions are generated by catalytic reactions at the anode, pass through the solid polymer electrolyte membrane, and are moved to the cathode.

[0013]

A fuel supply portion 21 connected to the fuel electrode side of the fuel cell 11 comprises, for example, a pressure control portion 22 for supplying hydrogen gas with a pressure depending on a control signal from the ECU18 or the air provided by the air compressor 15 as a signaling pressure.

The air compressor 15 connected to the air electrode side of the fuel cell 11 not only supplies air to the air electrode, but also supplies air as a signaling pressure to the pressure control portion 22 comprising a pressure flow control valve. Because of this, a control portion 23 of the air compressor 15 receives N from the ECU 18, where N is a command value for the number of revolutions of a motor that drives the air compressor 15.

[0014]

The power storage unit 12 is a capacitor such as an electric double-layer capacitor or an electrolytic capacitor. In addition, the fuel cell 11 and the power storage unit 12 are connected in parallel and are also connected to the driving motor 13, which is an electric load.

[0015]

Furthermore, a primary pre-charge portion 16 is disposed at the output side of the power storage unit 12, and a secondary pre-charge portion 17 is disposed at the output side of the fuel cell 11.

As shown in Fig. 2, the primary pre-charge portion 16 is provided with a high voltage switch 16a and a current limiter 16b. And, when the current to be supplied to the electric load such as the driving motor 13 and the like becomes large, the high voltage switch 16a is opened, and, also, the current limiter 16b, which is provided with a resistor 16c having a predetermined resistance value, is closed. As a result, the current is directed to flow through the resistor 16c.

For this operation, the high voltage switch 16a is provided with, for example,



relays which are connected to the respective output terminals of the positive and negative electrodes of the power storage unit 12, and are controlled by a control signal from the ECU 18 for a switching operation.

The current limiter 16b is connected to the high voltage switch 16a in parallel. The current limiter 16b is provided with a relay, which is connected to each output of the positive and negative electrodes of the power storage unit 12, and a resistor 16c with a predetermined resistance value. The electric current from the power storage unit 12 is supplied to the PDU 14 through the resistor 16c.

[0016]

The secondary pre-charge portion 17 comprises, for example, a DC-DC chopper 17a and a control portion 17b, and controls the output current  $I_{fc}$  from the fuel cell 11 based on a current command value  $IFCCMD$  from the ECU 18, that is, the electric generation command to the fuel cell 11.

As shown in Fig. 3, the DC-DC chopper 17a controls the ON/OFF operation of a transistor TR by supplying a pulse current to the base of the transistor TR from the control portion 17b, for example. When the output current becomes large, the control portion 17b limits the output current by changing the duty ratio of the pulse current in order that the OFF state of the transistor TR becomes longer.

Note that a diode disposed between the primary charge portion 16 and the secondary charge portion 17 in order to prevent a reverse current from flowing from the power storage unit 12 to the fuel cell 11.

[0017]

Also, as shown in Fig. 1, the control portion 23 of the air compressor 15, in addition to the PDU 14, is connected to the fuel cell 11 through the secondary pre-charge portion 17 in parallel.

A 12-V auxiliary battery 24 for driving various control devices and accessory devices of the fuel cell vehicle 1 is provided with a DC-DC converter 25, for example, which charges the auxiliary battery 24 after bringing down the DC voltage supplied from the fuel cell 11 through the secondary pre-charge portion 17.

In addition, a control apparatus 27 of a motor 26 for driving the air conditioner is connected to the fuel cell 11 through the secondary pre-charge portion 17 in parallel, and the control apparatus 27 converts DC electric power output from the fuel cell 11 and the power storage unit 12 into AC power to be supplied to the motor 26.

[0018]

The ECU 18 comprises, for example, a motor ECU 31, a fuel cell control portion 32, and a power storage unit control portion 33.

The motor ECU 31 controls the power conversion operation of the PWM inverter provided in the PDU 14, and sends switching commands such as a U phase AC voltage command value  $*V_u$ , a V phase AC voltage command value  $*V_v$ , and a W phase AC voltage command value  $*V_w$  to the PDU 14. Then, the PDU 14 sends a U phase current  $I_u$ , a V-phase current  $I_v$ , and a W-phase current  $I_w$  according to these voltage command values  $*V_u$ ,  $*V_v$ , and  $*V_w$  to respective phases of the driving motor 13.

For this operation, the motor ECU 31 receives various input signals, for example, a signal of an accelerator operational amount  $\theta_{Th}$  related to a depressing operation of the accelerator pedal by the driver and the like, a signal of a magnetic pole position (electric angle) output from an angular velocity detector 35 provided in the driving motor 13 for detecting the magnetic pole position, signals of the respective phase currents  $I_u$ ,  $I_v$ , and  $I_w$  supplied from the PDU 14 to the driving motor 13, a signal of a motor current  $I_{motor}$  of a DC component, and a signal of a supply voltage  $V_{dc-in}$  supplied to the PDU 14.

[0019]

The fuel cell control portion 32 outputs the number of rotation command value  $N$  as a command to drive the auxiliary devices such as the air compressor 15 that drives the fuel cell, and also controls the operations of the primary and secondary pre-charge portions 16 and 17. And, the fuel cell control portion 32 controls the operations of the contact points of relays which are provided in the high voltage switch 16a and the current limiter 16b of the primary pre-charge portion 16. The fuel cell control portion 32 also outputs a current command value  $IFCCMD$  to the DC-DC chopper 17a of the secondary pre-charge portion 17 as a switching command.

For the above control, the fuel cell control portion 32 receives various input signals, for example, a signal related to an output request value  $*P$  (output from the motor ECU 31) for the driving motor 13 and an output value  $P$  from the driving motor 13, a signal of a motor current  $I_{s/c}$  (output from the control portion 23) for a motor for driving the air compressor 15, signals of the output current  $I_{fc}$  and output voltage  $V_{fc}$  from the fuel cell 11, both being output from the secondary pre-charge portion 17, a signal of a DC voltage  $V_{dc-out}$  output from the DC-DC chopper 17a of the secondary pre-charge portion 17, and a signal of an output current value  $I_{out-Total}$  output from a current detector 36 disposed between the primary pre-charge portion 16 and the secondary pre-charge portion 17.

[0020]

The power storage unit control portion 33 calculates, for example, a remaining

charge SOC of the power storage unit 12 and sends the calculated result to the motor ECU 31 and the fuel cell control portion 32.

For this operation, the power storage unit 33 receives signals from the power storage unit 12 such as an output current  $I_{st}$ , a terminal voltage  $V_{st}$ , and a temperature  $T_{st}$  of the power storage unit 12.

[0021]

That is, as shown in Fig. 2, the ECU 18, which controls the current limiting process of the primary and secondary pre-charge portions 16 and 17, receives various signals such as a signal from a first current detector 41 which detects the output current  $I_{st}$  from the power storage unit 12, a signal from a first voltage detector 42 for detecting the terminal voltage  $V_{st}$  between the terminals of the power storage unit 12, a signal from a second current detector 43 for detecting an output current  $I_{fc}$  from the fuel cell 11, a signal from a second voltage detector 44 for detecting an output voltage  $V_{fc}$  of the fuel cell 11, and a signal from a third voltage detector 45 for detecting a motor voltage  $V_{MOT}$  of the driving motor 13.

[0022]

The control apparatus 10 for starting the fuel cell vehicle according to the present embodiment has the structure as described above, and the operations of the control apparatus 10 for starting the fuel cell vehicle, particularly the current control process of the primary and secondary pre-charge portions 16 and 17 at the time of starting the fuel cell vehicle 1 are explained below with reference to the attached drawings.

Fig. 4 is a flowchart showing the operation of the control apparatus 10 for starting the fuel cell vehicle, and Fig. 5 is a graph showing changes of the output voltage  $V_{fc}$  and the output current  $I_{fc}$  of the fuel cell 11, and the terminal voltage  $V_{st}$  of the power storage unit 12, and the connection flag of the high voltage switch 16a.

[0023]

For example, at the time of starting the vehicle and the like, the fuel cell 11, the power storage unit 12, and the PDU 14 are disconnected from each other, thus, the values of the output voltage  $V_{fc}$ , the terminal voltage  $V_{st}$ , and the motor voltage  $V_{MOT}$  are different from each other.

First, in step S01 shown in Fig. 4, a current limiting process is performed by the primary pre-charge portion 16. That is, the contact point of each relay of the high voltage switch 16a is opened, and the contact point of each relay in the current limiter 16b is closed so that the current output from the power storage unit 12 is directed through the resistor 16c.

[0024]

Next, in step S02, after the motor voltage  $V_{MOT}$  and the terminal voltage  $V_{fc}$  reach an equilibrium state, that is, a state where  $V_{MOT} \doteq V_{st}$ , the contact point of each relay of the high voltage switch 16a is closed.

Then, in step S03, the contact point of each relay of the high voltage switch 16b is opened. As a result, the output current from the power storage unit 12 is directed through the high voltage switch 16a and, for example, a condition, where  $V_{MOT} \doteq V_{st} \neq V_{fc}$ , is reached.

[0025]

Then, in step S04, the fuel cell 11 is started. That is, the air compressor 15 is started, which is used for supplying air not only to the air electrode of the fuel cell 11 but also to the pressure control portion 22 as a signaling pressure for supplying fuel to the fuel cell 11. Thus, since the electric power for driving the air compressor 15 is supplied from the power storage unit 12, the energy of the power storage unit 12 is getting reduced.

Next, in step S05, the terminal voltage  $V_{st}$  of the power storage unit 12 is detected by the first voltage detector 42 and the output voltage  $V_{fc}$  of the fuel cell 11 is detected by the first voltage detector 44.

[0026]

Next, in step S06, it is determined whether or not a value obtained by subtracting the terminal voltage  $V_{st}$  of the power storage unit 12 from the output voltage  $V_{fc}$  of the fuel cell 11 is larger than a predetermined voltage difference  $\Delta V$ .

If the determination is "YES", then the flow proceeds to step S07. And, in the secondary pre-charge portion 17, the output current from the DC-DC chopper 17a is limited to a predetermined current value, then, the processing of step S05 and the steps following step S05 is performed.

[0027]

On the other hand, when the determination in step S06 is "NO", the flow proceeds to step S08. A transient limit mode is set, that is, the current output from the DC-DC chopper 17a of the secondary pre-charge portion 17 is set to a value corresponding to the amounts of hydrogen gas and air to be supplied to the fuel cell 11. And, a series of processing steps are completed.

[0028]

That is, for example, as shown in Fig. 5, when controlling the output current  $I_{fc}$  of the fuel cell 11 by the DC-DC chopper 17a of the secondary pre-charge portion 17, it is possible to adjust the time required for the output voltage  $V_{fc}$  of the fuel cell 11 and

the terminal voltage  $V_{st}$  of the power storage unit 12 to reach the equilibrium voltages ( $V_{MOT} \rightleftharpoons V_{st} \rightleftharpoons V_{fc}$ ) by changing the duty ratio of the switching command input into the DC-DC chopper 17a.

[0029]

As described above, in the control apparatus 10 for starting the fuel cell vehicle according to the embodiment of the present invention, at the time of starting the fuel cell 11, first, the current from the power storage unit 12 is directed through the resistor 16c by the primary pre-charge portion 16 disposed at the output side of the power storage unit 12. Therefore, it is possible to prevent development of so-called an inrush current, that is, a large current rapidly flowing into capacitors (for example, the electrolytic capacitors as shown in Fig. 1). The electrolytic capacitors are provided at the input sides of, for example, the PDU14, the control portion 23 of the air compressor 15, and the DC-DC converter 25.

In addition, after the voltage at the load side such as the motor voltage  $V_{MOT}$  and the like becomes approximately equal to the terminal voltage  $V_{st}$  of the power storage unit 12, by limiting the output current  $I_{fc}$  of the fuel cell 11 using the secondary pre-charge portion 17, a large current is prevented from rapidly flowing into the power storage unit 12, where, the terminal voltage  $V_{st}$  of the power storage unit 12 has been reduced by supplying power to the auxiliary devices (such as the air compressor 15) for driving the fuel cell. Therefore, it is possible to prevent an excessive reduction of the output voltage  $V_{fc}$  of the fuel cell 11 during a transitional stage where the terminal voltage  $V_{st}$  of the power storage unit 12 is changing toward an equilibrium voltage.

[0030]

In addition, the use of the DC-DC chopper 17a in the secondary pre-charge portion 17 enables to control the output current of the fuel cell 11 easily by changing the duty of the pulse current received for controlling the chopping operation. Thus, it is possible to reduce the time for the output voltage  $V_{fc}$  of the fuel cell 11 and the terminal voltage of the power storage unit 12 to reach an equilibrium voltage, while preventing an excessive reduction of the output voltage  $V_{fc}$  of the fuel cell 11.

Even when the difference between the output voltage  $V_{fc}$  of the fuel cell 11 and the terminal voltage  $V_{st}$  of the power storage unit 12 is large, the DC-DC chopper 17a can prevent the development of an arc welding problem of a contact point when the contact point is opened. The arc welding problem is typically developed in a contact point type switching system such as the pre-charge portion 16 when the output path is switched to direct the electric current through the resistor 16c.

[0031]

Furthermore, as the primary pre-charge portion 16 in the present embodiment, a chopper system using a DC-DC chopper is used as the current limiting circuit. However, the system for performing the current limiting control is not only limited to the chopper system, but a variant such as a transistor-type current limiting circuit, or a depletion-type FET system current limiting circuit can be used.

[0032]

[Effects of the Invention]

As described above, a control apparatus for starting a fuel cell vehicle according to claim 1 of the present invention enables to prevent rapid reduction of the terminal voltage of a fuel cell by implementing current limiting means. The current limiting means limits the output current at the time of starting the fuel cell.

That is, even when, as a result of driving a fuel cell, the energy of a power storage unit has been consumed and the terminal voltage becomes low, a large amount of electric current can be prevented from flowing rapidly from the fuel cell into the power storage unit. As the output electrical current, which has been limited, gradually charges the power storage unit, the terminal voltage of the power storage unit and the terminal voltage of the fuel cell are gradually changed toward an equilibrium voltage with respect to each other. Typically, when the terminal voltage of the fuel cell becomes much lower than a predetermined voltage during the transitional stage toward the equilibrium voltage, the following problems may be developed. That is, hydrogen gas or the water content in the solid polymer electrolyte membrane of the fuel cell is evaporated or the durability of the fuel cell is decreased. However, since the terminal voltage of the fuel cell does not become lower than a predetermined voltage according to the present invention, the problems described above are avoided. Therefore, the control apparatus according to the present invention can contribute to lengthening the service life of the fuel cell.

[Brief Description of the Drawings]

[Figure 1]

Fig. 1 is a diagram showing the structure of a fuel cell vehicle provided with a control apparatus for starting the fuel cell vehicle according to an embodiment of the present invention.

[Figure 2]

Fig. 2 is a diagram showing the main structure of the control apparatus for starting the fuel cell vehicle shown in Fig. 1.

[Figure 3]

Fig. 3 is a diagram showing a configuration of the DC-DC chopper shown in Fig. 1.

[Figure 4]

Fig. 4 is a flowchart showing the operation of the control apparatus for starting the fuel cell vehicle shown in Fig. 1.

[Figure 5]

Fig. 5 is a graph showing changes of the output voltage  $V_{fc}$  and the output current  $I_{fc}$  of the fuel cell, the terminal voltage  $V_{st}$  of the power storage unit, and the connection flag of the high voltage switch.

[Brief Description of the Reference Symbols]

- 1 FUEL CELL VEHICLE
- 10 CONTROL APPARATUS FOR STARTING FUEL CELL VEHICLE
- 11 FUEL CELL
- 12 POWER STORAGE UNIT
- 15 AIR COMPRESSOR (FUEL CELL DRIVING MEANS)
- 17 SECONDARY PRE-CHARGE PORTION (ELECTRIC CURRENT LIMITING MEANS)

[Document Type] Drawing

[Document Type] Abstract

[Abstract]

[Problem to be Solved by the Invention]

To prevent the terminal voltage of a fuel cell from becoming excessively low when starting the fuel cell.

[Means for Solving the Problem]

A primary pre-charge portion 16 is disposed at the output side of a power storage unit 12 and a secondary pre-charge portion 17 is disposed at the output side of a fuel cell 11. The pre-charge portion 16 comprises a high voltage switch 16a and a current limiter 16b with a resistor 16c having a predetermined resistance. When an electric current supplied to an electric load such as a driving motor 13 and the like becomes large, the high voltage switch 16a is opened and the current limiter 16b is closed so that the electric current flows through the resistor 16c. The secondary pre-charge portion 17 comprises a DC-DC chopper 17a and a control portion 17b, and

controls the output current  $I_{fc}$  from the fuel cell 11 based on a current command value IFCCMD from ECU, that is, a command to the fuel cell 11 to perform electric generation.

[Elected Drawing] Fig. 2



Correction to the Fig. 4

In S06

Correct:  $(V_{fc} - V_{st}) \geq \Delta V?$

Incorrect:  $(V_{fc} - V_{st}) > \_V?$